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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No. 243777676US

INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Jaume	Anguera Pros	Vinaros, Spain

Additional inventors are being named on the 1 *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

Multi-Band Monopole Antennas for Mobile Communications Devices

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

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ENCLOSED APPLICATION PARTS *(check all that apply)*

☑ Specification *Number of Pages* 16
☑ Drawing(s) *Number of Sheets* 18
☐ Application Data Sheet. See 37 CFR 1.76
☐ CD(s), Number
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Respectfully submitted,

SIGNATURE Michael R. Asam

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Date January 30, 2004

REGISTRATION NO. 51,417
(if appropriate)
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Docket Number	153454600012

INVENTOR(S)/APPLICANT(S)		
Given Name (first and middle [if any])	Family or Surname	Residence (City and either State or Foreign Country)
Carles	Puente Baliarda	Barcelona, Spain

[Page 2 of 2]

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Effective 10/01/2003. Patent fees are subject to annual revision.

☐ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($) 160.00

Complete if Known	
Application Number	
Filing Date	
First Named Inventor	Jaume Anguera Pros
Examiner Name	
Art Unit	
Attorney Docket No.	153454600012

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☐ Check ☐ Credit card ☐ Money Order ☐ Other ☐ None

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FEE CALCULATION

1. BASIC FILING FEE

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1001	770	2001	385	Utility filing fee	
1002	340	2002	170	Design filing fee	
1003	530	2003	265	Plant filing fee	
1004	770	2004	385	Reissue filing fee	
1005	160	2005	80	Provisional filing fee	160

SUBTOTAL (1) ($) 160.00

2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

			Extra Claims		Fee from below		Fee Paid
Total Claims		-20** =		X		=	
Independent Claims		- 3** =		X		=	
Multiple Dependent						=	

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
1202	18	2202	9	Claims in excess of 20
1201	86	2201	43	Independent claims in excess of 3
1203	290	2203	145	Multiple dependent claim, if not paid
1204	86	2204	43	** Reissue independent claims over original patent
1205	18	2205	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) -0-

**or number previously paid, if greater; For Reissues, see above

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1051	130	2051	65	Surcharge - late filing fee or oath	
1052	50	2052	25	Surcharge - late provisional filing fee or cover sheet	
1053	130	1053	130	Non-English specification	
1812	2,520	1812	2,520	For filing a request for *ex parte* reexamination	
1804	920*	1804	920*	Requesting publication of SIR prior to Examiner action	
1805	1,840*	1805	1,840*	Requesting publication of SIR after Examiner action	
1251	110	2251	55	Extension for reply within first month	
1252	420	2252	210	Extension for reply within second month	
1253	950	2253	475	Extension for reply within third month	
1254	1,480	2254	740	Extension for reply within fourth month	
1255	2,010	2255	1,005	Extension for reply within fifth month	
1401	330	2401	165	Notice of Appeal	
1402	330	2402	165	Filing a brief in support of an appeal	
1403	290	2403	145	Request for oral hearing	
1451	1,510	1451	1,510	Petition to institute a public use proceeding	
1452	110	2452	55	Petition to revive - unavoidable	
1453	1,330	2453	665	Petition to revive - unintentional	
1501	1,330	2501	665	Utility issue fee (or reissue)	
1502	480	2502	240	Design issue fee	
1503	640	2503	320	Plant issue fee	
1460	130	1460	130	Petitions to the Commissioner	
1807	50	1807	50	Processing fee under 37 CFR 1.17(q)	
1806	180	1806	180	Submission of Information Disclosure Stmt	
8021	40	8021	40	Recording each patent assignment per property (times number of properties)	
1809	770	2809	385	Filing a submission after final rejection (37 CFR 1.129(a))	
1810	770	2810	385	For each additional invention to be examined (37 CFR 1.129(b))	
1801	770	2801	385	Request for Continued Examination (RCE)	
1802	900	1802	900	Request for expedited examination of a design application	

Other fee (specify) ______

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SUBMITTED BY				(Complete *(if applicable)*)
Name *(Print/Type)*	Michael R. Asam	Registration No. (Attorney/Agent)	51,417	Telephone 216-586-7770
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EV243777676US

PROVISIONAL U.S. PATENT APPLICATION

for

Multi-Band Monopole Antennas For Mobile Communications Devices

Inventors:

Jaume Anguera

Carles Puente

CLI-1154566v1

INTRODUCTION

This invention relates generally to the field of multi-band monopole internal and external antennas. More specifically, multi-band monopole antennas are provided that are particularly well-suited for use in mobile communications devices, such as Personal Digital Assistants, cellular telephones, and pagers.

BACKGROUND

Multi-band antenna structures for use in a mobile communications device are known in this art. For example, one type of antenna structure that is commonly utilized as an internally-mounted antenna for a mobile communication device is known as an "inverted-F" antenna. When mounted inside a mobile communications device, an antenna is often subject to problematic amounts of electromagnetic interference from other metallic objects within the mobile communications device, particularly from the ground plane. An inverted-F antenna has been shown to perform adequately as an internally mounted antenna, compared to other known antenna structures. Inverted-F antennas, however, are typically bandwidth-limited, and thus may not be well suited for bandwidth intensive applications. An example of an antenna structure that is used as an externally mounted antenna for a mobile communication device is known as a space-filling or grid dimension antenna. External mounting reduces the amount of electromagnetic interference from other metal objects within the mobile communication device.

SUMMARY

Multi-band monopole antennas are disclosed. The antennas disclosed can include a substrate with a first side and a second side, a first conductor located on the first side of the antenna substrate, and a second conductor located on the second side of the antenna substrate. The conductors can have multiple branches. If a conductor has multiple branches, each branch can be set up to receive a different frequency band. A conductor with multiple branches can have a linear branch and a space-filling branch. A conductor can also be a conducting plate. A conducting plate can act as a parasitic reflector plane to tune or partially tune the resonant frequency of another conductor.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a top view of an exemplary multi-band monopole antenna for a mobile communications device;

Fig. 2 is a top view of an exemplary multi-band monopole antenna including one alternative space-filling geometry;

Figs. 3-9 illustrate several alternative multi-band monopole antenna configurations;

Fig. 10 is a top view of the exemplary multi-band monopole antenna of Fig. 1 coupled to a circuit board for a mobile communications device;

Figs. 11 shows an exemplary mounting structure for securing a multi-band monopole antenna within a mobile communications device;

Fig. 12 is an exploded view of an exemplary clamshell-type cellular telephone having a multi-band monopole antenna;

Fig. 13 is an exploded view of an exemplary candy-bar-style cellular telephone having a multi-band monopole antenna; and

Fig. 14 is an exploded view of an exemplary personal digital assistant (PDA) having a multi-band monopole antenna.

Fig. 15 shows one example of a space-filling curve;

Figs. 16-19 illustrate an exemplary two-dimensional antenna geometry forming a grid dimension curve;

Fig. 20 is a three-dimensional view of a double-sided, double-surface antenna with two spiral conductors.

Fig. 21 is a three-dimensional view of a double-sided, double-surface antenna with a dual branched antenna and a conducting plate.

Fig. 22 is a color photograph of several antenna examples, including A1, A2, H1-Rog, H2-Rog, C7, H1 and H2 antennas.

Fig. 23 is a color photograph of a modified antenna configuration designated H1-mod that is based on the H2 antenna shown in Fig. 22.

Fig. 24 is a color photograph of antennas C7-2, C7-3, C7-4 and C7-5, which are based on modifications to the C7 antenna shown in Fig. 22.

Fig. 25 is a color photograph of five examples of the C7-4 antenna contained in external antenna housings.

DETAILED DESCRIPTION

Referring now to the drawing figures, Fig. 1 is a top view of an exemplary multi-band monopole antenna 10 for a mobile communications device. The multi-band monopole antenna 10 includes a first radiating arm 12 and a second radiating arm 14 that are both coupled to a feeding port 17 through a common conductor 16. The antenna 10 also includes a substrate material 18 on which the antenna structure 12, 14, 16 is fabricated, such as a dielectric substrate, a flex-film substrate, or some other type of suitable substrate material. The antenna structure 12, 14, 16 is preferably patterned from a conductive material, such as a metallic thick-film paste that is printed and cured on the substrate material 18, but may alternatively be fabricated using other known fabrication techniques.

The first radiating arm 12 includes a meandering section 20 and an extended section 22. The meandering section 20 is coupled to and extends away from the common conductor 16. The extended section 22 is contiguous with the meandering section 20 and extends from the end of the meandering section 20 back towards the common conductor 16. In the illustrated embodiment, the meandering section 20 of the first radiating arm 12 is formed into a geometric shape known as a space-filling curve, in order to reduce the overall size of the antenna 10. A space-filling curve is characterized by at least ten segments which are connected in such a way that each segment forms an angle with its adjacent segments, that is, no pair of adjacent segments define a larger straight segment. It should be understood, however, that the meandering section

20 may include other space-filling curves than that shown in Fig. 1, or may optionally be arranged in an alternative meandering geometry. Figs. 2-6, for example, illustrate antenna structures having meandering sections formed from several alternative geometries. The use of shape-filling curves to form antenna structures is described in greater detail in the co-owned PCT Application WO 01/54225, entitled Space-Filling Miniature Antennas, which is hereby incorporated into the present application by reference.

The second radiating arm 14 includes three linear portions. As viewed in Fig. 1, the first linear portion extends in a vertical direction away from the common conductor 16. The second linear portion extends horizontally from the end of the first linear portion towards the first radiating arm. The third linear portion extends vertically from the end of the second linear portion in the same direction as the first linear portion and adjacent to the meandering section 20 of the first radiating arm 14.

As noted above, the common conductor 16 of the antenna 10 couples the feeding port 17 to the first and second radiating arms 12, 14. The common conductor 16 extends horizontally (as viewed in Fig. 1) beyond the second radiating arm 14, and may be folded in a perpendicular direction (perpendicularly into the page), as shown in Fig. 10, in order to couple the feeding port 17 to communications circuitry in a mobile communications device.

Operationally, the first and second radiating arms 12, 14 are each tuned to a different frequency band, resulting in a dual-band antenna. The antenna 10 may be tuned to the desired dual-band operating frequencies of a mobile communications device by pre-selecting the total conductor length of each of the radiating arms 12, 14. For example, in the illustrated embodiment, the first radiating arm 12 may be tuned to operate in a lower frequency band or groups of bands, such as PDC (800 MHz), CDMA (800 MHz), GSM (850 MHz), GSM (900 MHz), GPS, or some other desired frequency band. Similarly, the second radiating arm 14 may be tuned to operate in a higher frequency band or group of bands, such as GPS, PDC (1500 MHz), GSM (1800 MHz), Korean PCS, CDMA/PCS (1900 MHz), CDMA2000/UMTS, IEEE 802.11 (2.4 GHz), or some other desired frequency band. It should be understood that, in some embodiments, the lower frequency band of the first radiating arm 12 may overlap the higher frequency band of the second radiating arm 14, resulting in a single broader band. It should also

be understood that the multi-band antenna 10 may be expanded to include further frequency bands by adding additional radiating arms. For example, a third radiating arm could be added to the antenna 10 to form a tri-band antenna.

Fig. 2 is a top view of an exemplary multi-band monopole antenna 30 including one alternative space-filling geometry. The antenna 30 show in Fig. 2 is similar to the multi-band antenna 10 shown in Fig. 1, except the meandering section 32 in the first radiating arm 12 includes a different space-filling curve than that shown in Fig. 1.

Figs. 3-9 illustrate several alternative multi-band monopole antenna configurations 50, 70, 80, 90, 93, 95, 97. Similar to the antennas 10, 30 shown in Figs. 1 and 2, the multi-band monopole antenna 50 illustrated in Fig. 3 includes a common conductor 52 coupled to a first radiating arm 54 and a second radiating arm 56. The common conductor 52 includes a feeding port 62 on a linear portion of the common conductor 52 that extends horizontally (as viewed in Fig. 3) away from the radiating arms 54, 56, and that may be folded in a perpendicular direction (perpendicularly into the page) in order to couple the feeding port 62 to communications circuitry in a mobile communications device.

The first radiating arm 54 includes a meandering section 58 and an extended section 60. The meandering section 58 is coupled to and extends away from the common conductor 52. The extended section 60 is contiguous with the meandering section 58 and extends from the end of the meandering section 58 in an arcing path back towards the common conductor 52.

The second radiating arm 56 includes three linear portions. As viewed in Fig. 3, the first linear portion extends diagonally away from the common conductor 52. The second linear portion extends horizontally from the end of the first linear portion towards the first radiating arm. The third linear portion extends vertically from the end of the second linear portion away from the common conductor 52 and adjacent to the meandering section 58 of the first radiating arm 54.

The multi-band monopole antennas 70, 80, 90 illustrated in Figs. 4-6 are similar to the antenna 50 shown in Fig. 3, except each includes a differently-patterned meandering portion 72, 82, 92 in the first radiating arm 54. For example, the meandering portion 92 of the multi-band

antenna 90 shown in Fig. 6 meets the definition of a space-filling curve, as described above. The meandering portions 58, 72, 82 illustrated in Figs. 3-5, however, each include differently-shaped periodic curves that do not meet the requirements of a space-filling curve.

The multi-band monopole antennas 93, 95, 97 illustrated in Figs. 7-9 are similar to the antenna 30 shown in Fig. 2, except in each of Figs. 7-9 the expanded portion 22 of the first radiating arm 12 includes an additional area 94, 96, 98. In Fig. 7, the expanded portion 22 of the first radiating arm 12 includes a polygonal portion 94. In Figs. 8 and 9, the expanded portion 22 of the first radiating arm 12 includes a portion 96, 98 with an arcuate longitudinal edge.

Fig. 10 is a top view 100 of the exemplary multi-band monopole antenna 10 of Fig. 1 coupled to the circuit board 102 of a mobile communications device. The circuit board 102 includes a feeding point 104 and a ground plane 106. The ground plane 106 may, for example, be located on one of the surfaces of the circuit board 102, or may be one layer of a multi-layer printed circuit board. The feeding point 104 may, for example, be a metallic bonding pad that is coupled to circuit traces 105 on one or more layers of the circuit board 102. Also illustrated, is communication circuitry 108 that is coupled to the feeding point 104. The communication circuitry 108 may, for example, be a multi-band transceiver circuit that is coupled to the feeding point 104 through circuit traces 105 on the circuit board.

In order to reduce electromagnetic interference from the ground plane 106, the antenna 10 is mounted within the mobile communications device such that the projection of the antenna footprint on the plane of the circuit board 102 does not intersect the metalization of the ground plane 106 by more than fifty percent. In the illustrated embodiment 100, the antenna 10 is mounted above the circuit board 102. That is, the circuit board 102 is mounted in a first plane and the antenna 10 is mounted in a second plane within the mobile communications device. In addition, the antenna 10 is laterally offset from an edge of the circuit board 102, such that, in this embodiment 100, the projection of the antenna footprint on the plane of the circuit board 102 does not intersect any of the metalization of the ground plane 106.

In order to further reduce electromagnetic interference from the ground plane 106, the feeding point 104 is located at a position on the circuit board 102 adjacent to a corner of the ground plane 106. The antenna 10 is preferably coupled to the feeding point 104 by folding a

portion of the common conductor 16 perpendicularly towards the plane of the circuit board 102 and coupling the feeding port 17 of the antenna 10 to the feeding point 104 of the circuit board 102. The feeding port 17 of the antenna 10 may, for example, be coupled to the feeding point 104 using a commercially available connector, by bonding the feeding port 17 directly to the feeding point 104, or by some other suitable coupling means. In other embodiments, however, the feeding port 17 of the antenna 10 may be coupled to the feeding point 104 by some means other than folding the common conductor 16.

Fig. 11 shows an exemplary mounting structure 111 for securing a multi-band monopole antenna 112 within a mobile communications device. The illustrated embodiment 110 employs a multi-band monopole antenna 112 having a meandering section similar to that shown in Fig. 2. It should be understood, however, that alternative multi-band monopole antenna configurations, as described in Figs 1-9, could also be used.

The mounting structure 111 includes a flat surface 113 and at least one protruding section 114. The antenna 112 is secured to the flat surface 113 of the mounting structure 111, preferably using an adhesive material. For example, the antenna 112 may be fabricated on a flex-film substrate having a peel-type adhesive on the surface opposite the antenna structure. Once the antenna 112 is secured to the mounting structure 111, the mounting structure 111 is positioned in a mobile communications device with the protruding section 114 extending over the circuit board. The mounting structure 111 and antenna 112 may then be secured to the circuit board and to the housing of the mobile communications device using one or more apertures 116, 117 within the mounting structure 111.

Fig. 12 is an exploded view of an exemplary clamshell-type cellular telephone 120 having a multi-band monopole antenna 121. The cellular telephone 120 includes a lower circuit board 122, an upper circuit board 124, and the multi-band antenna 121 secured to a mounting structure 110. Also illustrated are an upper and a lower housing 128, 130 that join to enclose the circuit boards 122, 124 and antenna 121. The illustrated multi-band monopole antenna 121 is similar to the multi-band antenna 30 shown in Fig. 2. It should be understood, however, that alternative antenna configurations, as describe above with reference to Figs. 1-9, could also be used.

The lower circuit board 122 is similar to the circuit board 102 described above with reference to Fig. 10, and includes a ground plane 106, a feeding point 104, and communications circuitry 108. The multi-band antenna 121 is secured to a mounting structure 110 and coupled to the lower circuit board 122, as described above with reference to Figs. 10 and 11. The lower circuit board 122 is then connected to the upper circuit board 124 with a hinge 126, enabling the upper and lower circuit boards 122, 124 to be folded together in a manner typical for clamshell-type cellular phones. In order to further reduce electromagnetic interference from the upper and lower circuit boards 122, 124, the multi-band antenna 121 is preferably mounted on the lower circuit board 122 adjacent to the hinge 126.

Fig. 13 is an exploded view of an exemplary candy-bar-type cellular telephone 200 having a multi-band monopole antenna 201. The cellular telephone 200 includes the multi-band monopole antenna 201 secured to a mounting structure 110, a circuit board 214, and an upper and lower housing 220, 222. The circuit board 214 is similar to the circuit board 102 described above with reference to Fig. 10, and includes a ground plane 106, a feeding point 104, and communications circuitry 108. The illustrated antenna 201 is similar to the multi-band monopole antenna shown in Fig. 3, however alternative antenna configurations, as described above with reference to Figs. 1-9, could also be used.

The multi-band antenna 201 is secured to the mounting structure 110 and coupled to the circuit board 214 as described above with reference to Figs. 10 and 11. The upper and lower housings 220, 222 are then joined to enclose the antenna 212 and circuit board 214.

Fig. 14 is an exploded view of an exemplary personal digital assistant (PDA) 230 having a multi-band monopole antenna 231. The PDA 230 includes the multi-band monopole antenna 231 secured to a mounting structure 110, a circuit board 236, and an upper and lower housing 242, 244. Although shaped differently, the PDA circuit board 236 is similar to the circuit board 102 described above with reference to Fig. 10, and includes a ground plane 106, a feeding point 104, and communications circuitry 108. The illustrated antenna 231 is similar to the multi-band monopole antenna shown in Fig. 5, however alternative antenna configurations, as described above with reference to Figs. 1-9, could also be used.

The multi-band antenna 231 is secured to the mounting structure 110 and coupled to the circuit board 214 as described above with reference to Figs. 10 and 11. In slight contrast to Fig. 10, however, the PDA circuit board 236 defines an L-shaped slot along an edge of the circuit board 236 into which the antenna 231 and mounting structure 110 are secured in order to conserve space within the PDA 230. The upper and lower housings 242, 244 are then joined together to enclose the antenna 231 and circuit board 236.

An example of a space-filling curve 250 is shown in Fig. 15. As mentioned above, space-filling means a curve formed from a line that includes at least ten segments, with each segment forming an angle with an adjacent segment. When used in an antenna, each segment in a space-filling curve 250 should be shorter than one-tenth of the free-space operating wavelength of the antenna.

In addition to space-filling curves, the curves described herein can also be grid dimension curves. Examples of grid dimension curves are shown in Figs. 16 to 19. The grid dimension of a curve may be calculated as follows. A first grid having square cells of length L1 is positioned over the geometry of the curve, such that the grid completely covers the curve. The number of cells (N1) in the first grid that enclose at least a portion of the curve are counted. Next, a second grid having square cells of length L2 is similarly positioned to completely cover the geometry of the curve, and the number of cells (N2) in the second grid that enclose at least a portion of the curve are counted. In addition, the first and second grids should be positioned within a minimum rectangular area enclosing the curve, such that no entire row or column on the perimeter of one of the grids fails to enclose at least a portion of the curve. The first grid should include at least twenty-five cells, and the second grid should include four times the number of cells as the first grid. Thus, the length (L2) of each square cell in the second grid should be one-half the length (L1) of each square cell in the first grid. The grid dimension (D_g) may then be calculated with the following equation:

$$D_g = -\frac{\log(N2) - \log(N1)}{\log(L2) - \log(L1)}$$

For the purposes of this application, the term grid dimension curve is used to describe a curve geometry having a grid dimension that is greater than one (1). The larger the grid

dimension, the higher the degree of miniaturization that may be achieved by the grid dimension curve in terms of an antenna operating at a specific frequency or wavelength. In addition, a grid dimension curve may, in some cases, also meet the requirements of a space-filling curve, as defined above. Therefore, for the purposes of this application a space-filling curve is one type of grid dimension curve.

Fig. 16 shows an exemplary two-dimensional antenna 260 forming a grid dimension curve with a grid dimension of approximately two (2). Fig. 17 shows the antenna 260 of Fig. 16 enclosed in a first grid 270 having thirty-two (32) square cells, each with length L1. Fig. 18 shows the same antenna 260 enclosed in a second grid 280 having one hundred twenty-eight (128) square cells, each with a length L2. The length (L1) of each square cell in the first grid 270 is twice the length (L2) of each square cell in the second grid 280 ($L2 = 2 \times L1$). An examination of Figs. 17 and 18 reveals that at least a portion of the antenna 260 is enclosed within every square cell in both the first and second grids 270, 280. Therefore, the value of N1 in the above grid dimension (D_g) equation is thirty-two (32) (i.e., the total number of cells in the first grid 270), and the value of N2 is one hundred twenty-eight (128) (i.e., the total number of cells in the second grid 280). Using the above equation, the grid dimension of the antenna 260 may be calculated as follows:

$$D_g = -\frac{\log(128) - \log(32)}{\log(2 \times L1) - \log(L1)} = 2$$

For a more accurate calculation of the grid dimension, the number of square cells may be increased up to a maximum amount. The maximum number of cells in a grid is dependent upon the resolution of the curve. As the number of cells approaches the maximum, the grid dimension calculation becomes more accurate. If a grid having more than the maximum number of cells is selected, however, then the accuracy of the grid dimension calculation begins to decrease. Typically, the maximum number of cells in a grid is one thousand (1000).

For example, Fig. 19 shows the same antenna 260 enclosed in a third grid 290 with five hundred twelve (512) square cells, each having a length L3. The length (L3) of the cells in the third grid 290 is one half the length (L2) of the cells in the second grid 280, shown in Fig. 18. As noted above, a portion of the antenna 260 is enclosed within every square cell in the second

grid 280, thus the value of N for the second grid 280 is one hundred twenty-eight (128). An examination of Fig. 19, however, reveals that the antenna 260 is enclosed within only five hundred nine (509) of the five hundred twelve (512) cells in the third grid 290. Therefore, the value of N for the third grid 290 is five hundred nine (509). Using Figs. 18 and 19, a more accurate value for the grid dimension (D_g) of the antenna 260 may be calculated as follows:

$$D_g = -\frac{\log(509) - \log(128)}{\log(2 \times L2) - \log(L2)} \approx 1.9915$$

The multi-band monopole antennas disclosed herein also include multiple conductor, double-sided, double-surface antenna arrangements. These multiple conductor, double-sided, double-surface antenna arrangements include all the aspects of the multi-band monopole antennas discussed above including, but not limited to, the physical properties of the substrate and conductive materials. In such double-sided, double-surface antenna arrangements, conductors are located on different surfaces of an antenna substrate. Each of the conductors can have the same or different geometry. Conductors on different sides of an antenna substrate can be physically, electrically connected or they may not be connected. Conductors on different sides of an antenna substrate can be connected by a coupling mechanism, e.g., an internal passage containing a conductor or an external conductor. Options for conductors include, but are not limited to, conductors with space-filling or grid dimension curves as discussed above, conductors with multiple arms as discussed above, and conducting plates that acts as parasitic reflector planes to tune the resonant frequency of a second band of another conductor.

Fig. 20 is an example of a double-sided, double-surface antenna 300 with two spiral conductors (302 and 304). An antenna substrate, may be included between the spiral conductors 304 and 306. Spiral conductor 304 may be located on the front face of an antenna substrate and conductor 306 may be located on the back face of an antenna substrate. Spiral conductor 302 is connected to a feeding port 306 and spiral conductor 302 is connected to spiral conductor 304 by connector 308. Connector 308 electrically connects spiral connectors 302 and 304 and would pass through an internal passage of the antenna substrate if shown.

Fig. 21 is an example of a double-sided, double-surface antenna 310 with a dual branched antenna 312 and feeding port 314 on one side (shown in blue) and a conducting plate 316 on the

other side (shown in green). The dual branched antenna 312 comprises two conductors: a space-filling or grid dimension section 318 and a linear section 320 (further examples of dual and multi-band antennas are discussed above). Similar to Fig. 20, an antenna substrate may be located between the dual branched antenna 312 and the conducting plate 316. The dual branched antenna 312 may be located on the front face of an antenna substrate and the conducting plate 316 may be located on the back face of an antenna substrate. Depending on the identity of plane 322 (shown in red), conducting plate 316 can either be an extension of the space-filling or grid dimension section 318 of the dual branched antenna 312 or a parasitic plane reflector. If the plane 322 is used to represent a conductor electrically connecting the end of the space-filling or grid dimension section 318 of the dual branched antenna 312 to the conducting plate 316, then the conducting plate acts as an extension of the space-filling or grid dimension section 318 of the dual branched antenna 312 and will also provide some of the tuning properties of a parasitic plane reflector. If the plane 322 is not a conductor connecting the end of the space-filling or grid dimension section 318 to the conducting plate 316, then the conducting plate acts as a parasitic plane reflector.

Other antenna examples are shown in Fig. 22. The antennas shown in Fig. 22 comprise conductors (reddish lines) located on antenna substrates. The column headings at the top of Fig. 22 provide designations for the antennas shown in the columns below the designations. The row designations on the left of the Fig. 22 indicate the front face, "a", and back face, "b", for each antenna. Antenna A1, shown in column A1, is a spiral antenna with one conductor shown on the front face. Antenna A2, shown in column A2, is a dual sided spiral antenna similar to the one shown in Fig. 20 and discussed above. Antenna H1-Rog, shown in column H1-Rog, is a Rogers made antenna with a Hilbert-like space-filling antenna on the front face and a parasitic reflector plate on the back face. Antenna H2-Rog, shown in column H2-Rog, is a Rogers made antenna with a dual branched Hilbert-like space-filling antenna on the front face and no conductor on the back face. Antenna C7, shown in column C7, is similar to the double-sided, double-surface antenna shown in Fig. 21 and discussed above. Antenna C7 has a double side branch on the front face and a partial conducting plate on the back face located behind the space-filling or grid dimension section of the dual branched conductor. The black "dots" located at the top of the space-filling or grid dimension section of the dual branched conductor and the partial conducting plate of antenna C7 are internal passages through the substrate through which the space-filling or

grid dimension portion of the dual branched conductor and the partial conducting plate are electrically connected. The conducting plate and space-filling or grid dimension section of the dual branched conductor can also be connected at any point along their common length. Antenna H1, shown in column H1, has a Hilbert-like space-filling line on the front face and a parasitic reflector plate on the back face. The conductor layout of antenna H1 is the same as for antenna H1-Rog, but the substrate is fiberglass. Antenna H2, shown in column H2, has a dual branched Hilbert-like space-filling antenna on the front face and no conductor on the back face. The conductor layout of antenna H2 is the same as for antenna H2-Rog, but the substrate is fiberglass.

Fig. 23 shows an antenna conductor configuration based on the H2 antenna shown in Fig. 22. This antenna configuration is designated H1-mod. The first modification of the H2 conductor configuration to create the H1-mod antenna is to disconnect the base connection of the linear section (350) of the dual branched Hilbert-like space-filling antenna and reconnect it at the end of the space-filling section of the dual branched Hilbert-like antenna (352). This modification helps to reduce the resonant frequency of the GSM900 band. The second modification is to add a conducting plate to the back face of the antenna substrate to create a parasitic plane reflector. The parasitic plane reflector will help tune the frequency of the GSM1800 band. A second new antenna, designated H1-modrog, uses the same conductor modifications on an H2-Rog antenna, i.e., different substrate.

Fig. 24 shows several additional antennas based on modifications to the C7 antenna discussed above. Each quadrant of Fig. 24 shows the front face (left side) and rear face (right side) of each new antenna. In these antennas, as discussed above with respect to the C7 antenna, the conducting plate on the rear face of the substrate and the space-filling or grid dimension section of the dual branched conductor are electrically connected by conductors passing through the substrate, i.e., the "black dots". The C7-2 antenna removes the downward portion of the straight line conductor (360) of the dual branched antenna and decreases the width (362) and length (364) of the conductor plate on the rear face. The C7-3 antenna removes the downward portion of the straight line conductor (366) of the dual branched antenna, removes the first set of turns in the space-filling or grid dimension section of the dual branched antenna by creating a solid conductor portion (368), and decreases the width of the conductor plate on the rear face

(370). The C7-4 antenna modifies the conductor plate (372) on the rear face. The C7-5 antenna also modifies the conductor plate (374) on the rear face.

Fig. 25 shows five examples of the C7-4 antenna contained in external antenna housings.

This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to make and use the invention. The patentable scope of the invention may include other examples that occur to those skilled in the art.

What is claimed is:

1. A multi-band monopole antenna for external use in a mobile communication device, comprising:

an antenna substrate with a base, a top, a front side and a back side;

a first conductor located on the front side of the antenna substrate, said first conductor comprising a dual branched antenna with a space-filling or grid dimension branch for receiving frequencies in the GSM900 band and a linear branch for receiving frequencies in the GSM1800 band; and

a second conductor located on the second side of the antenna substrate, said second conductor comprising a conducting plate that is positioned behind the space-filling or grid dimension branch of the dual branched antenna,

wherein the first conductor and the second conductor are electrically connected at the top of the antenna substrate through holes cut in the antenna substrate.

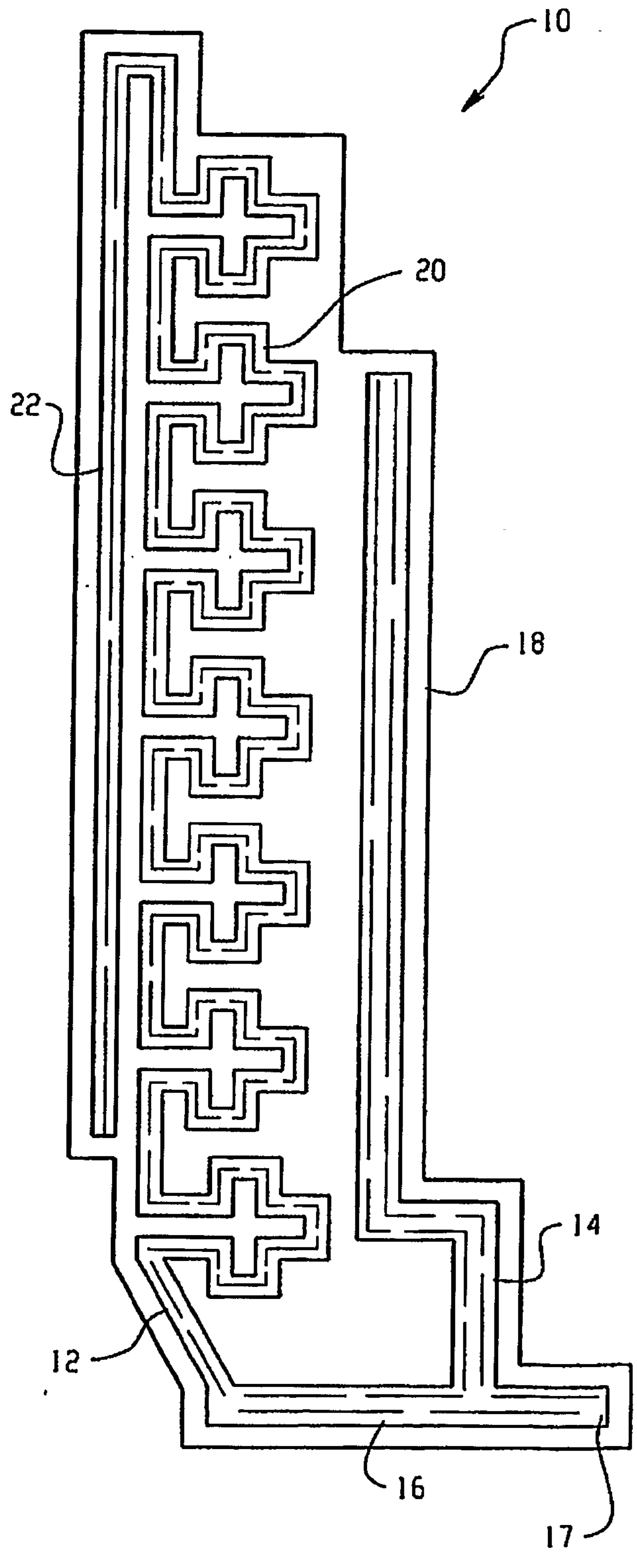

Fig. 1

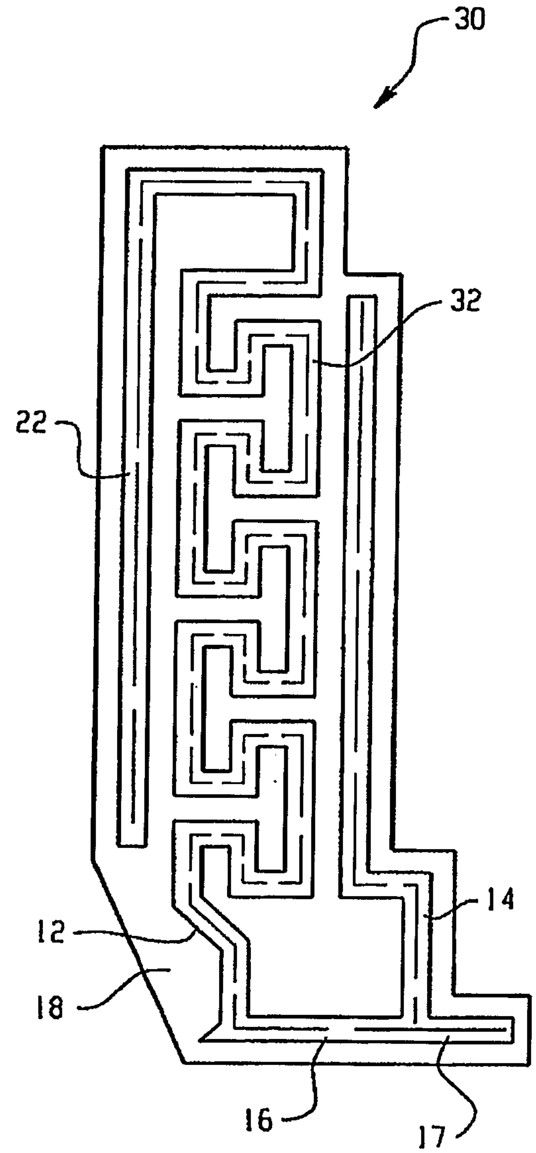

Fig. 2

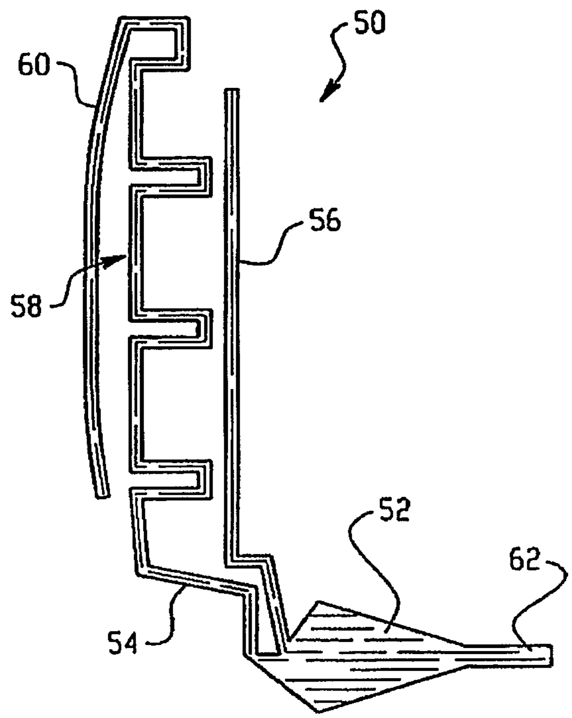

Fig. 3

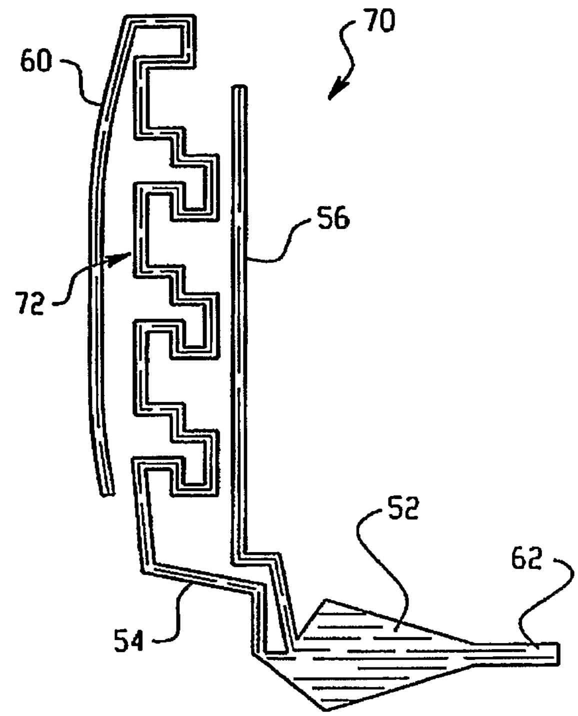

Fig. 4

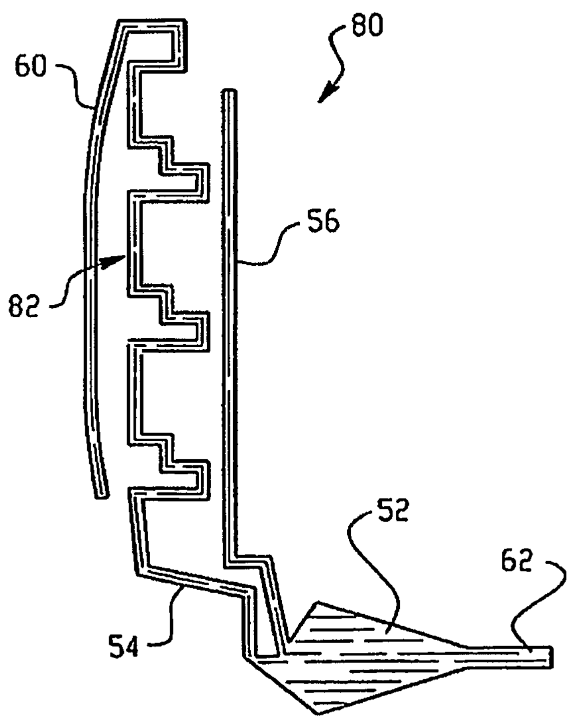

Fig. 5

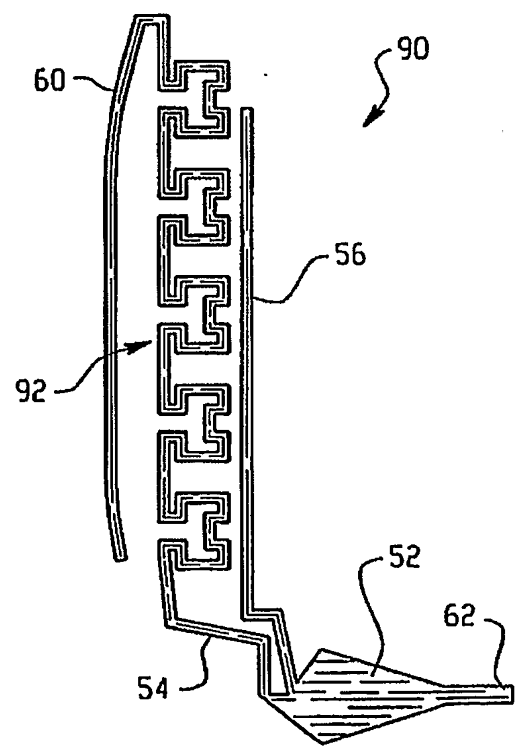

Fig. 6

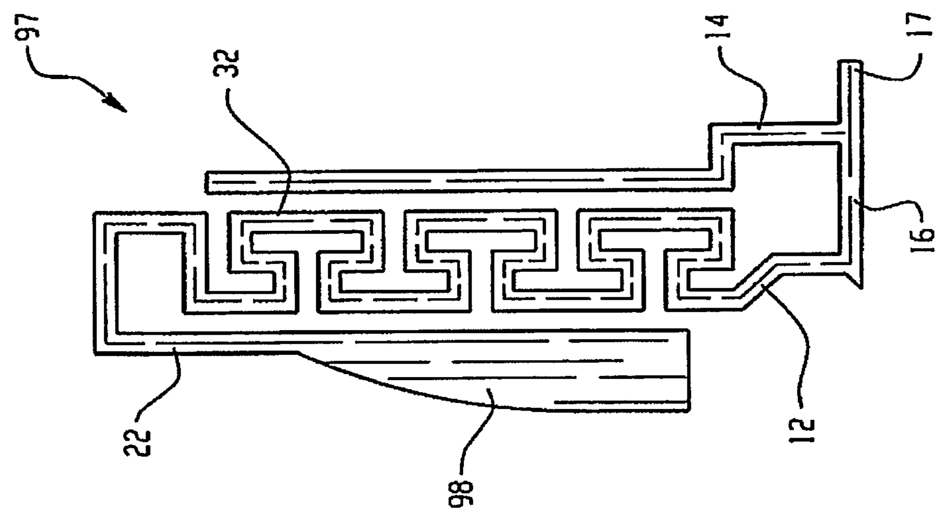

Fig. 9

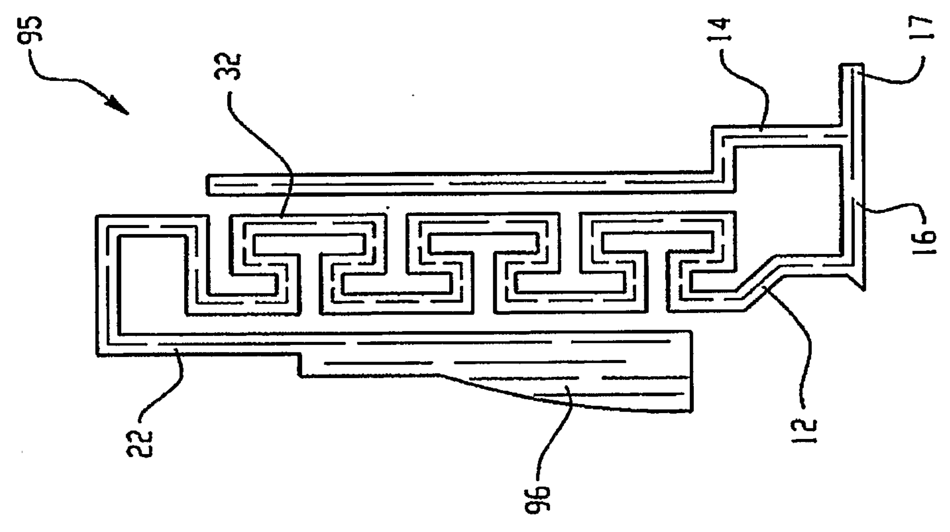

Fig. 8

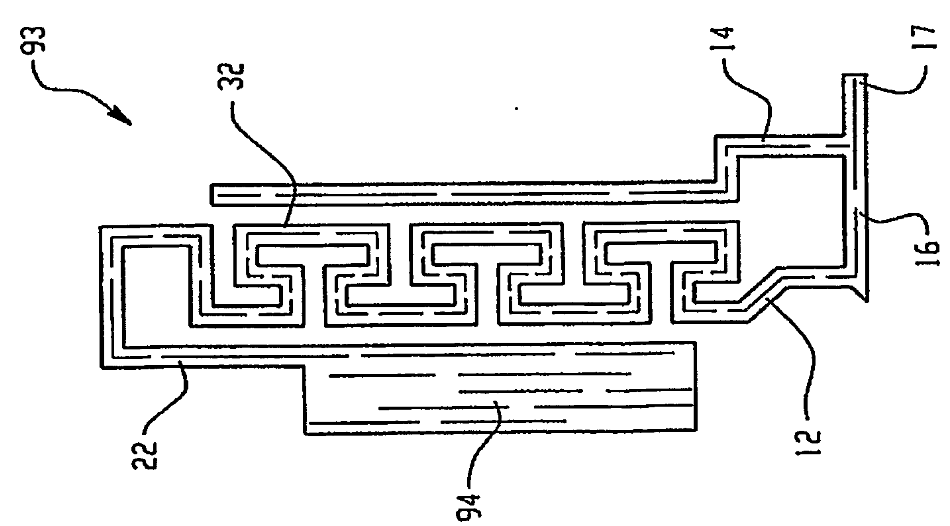

Fig. 7

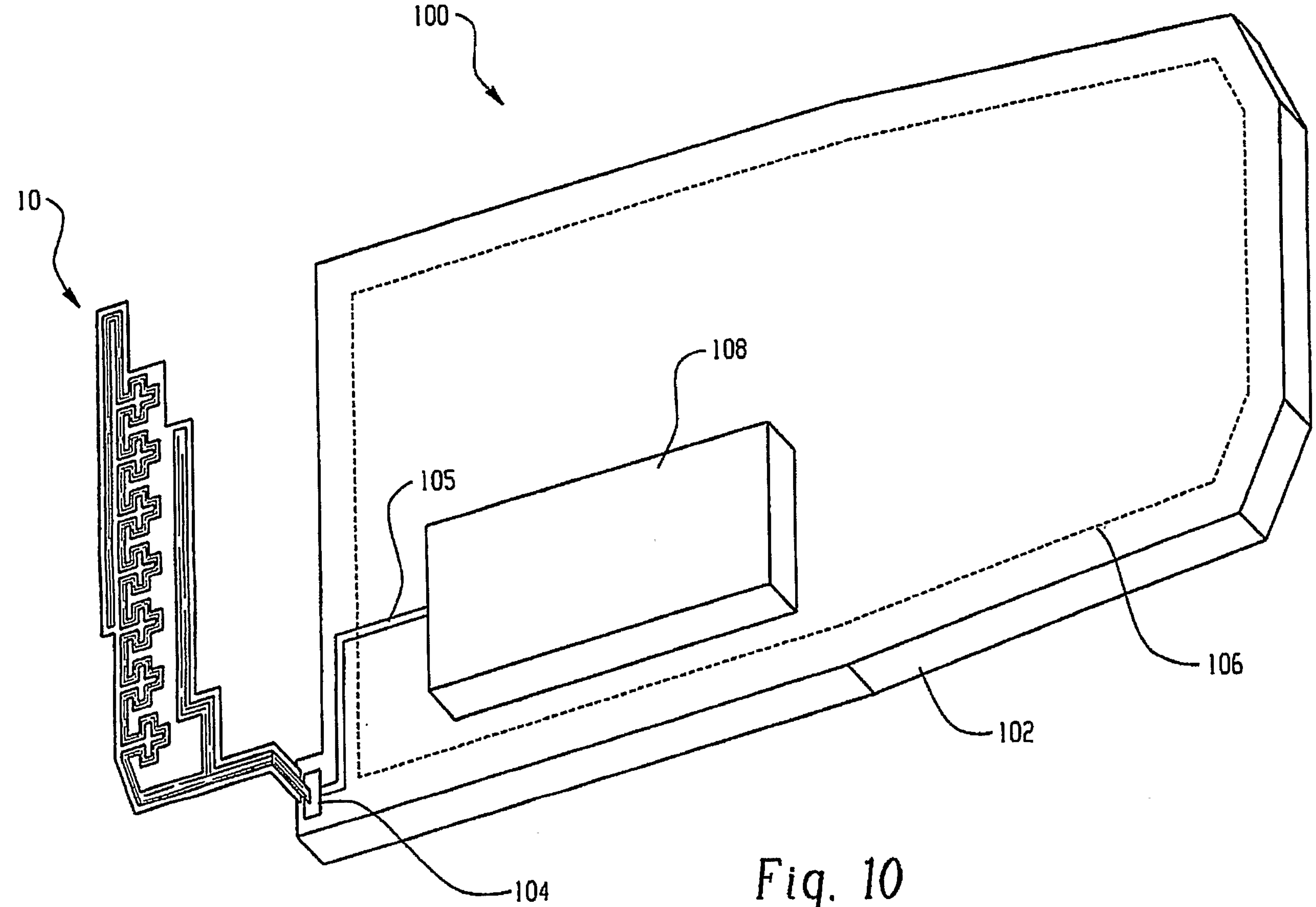

Fig. 10

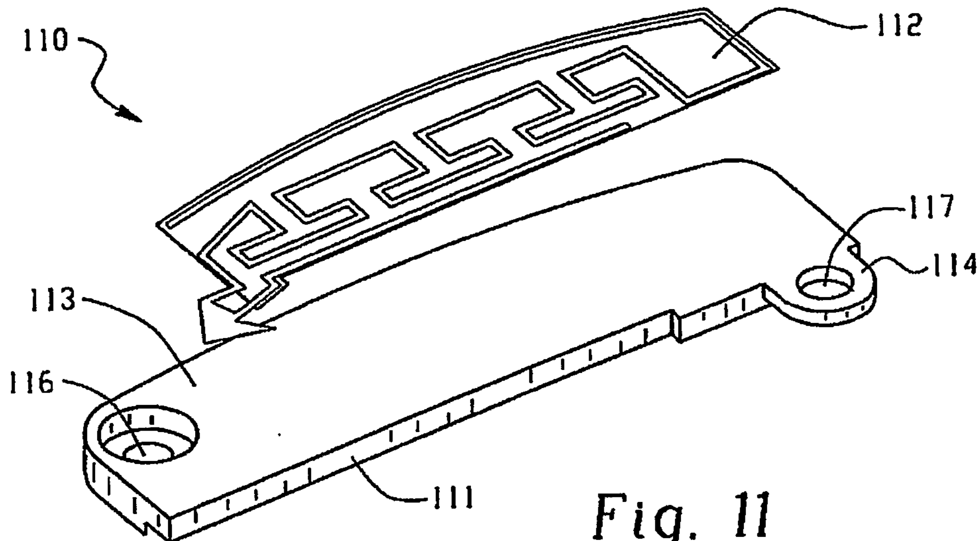
110
112
117
114
113
116
111

Fig. 11

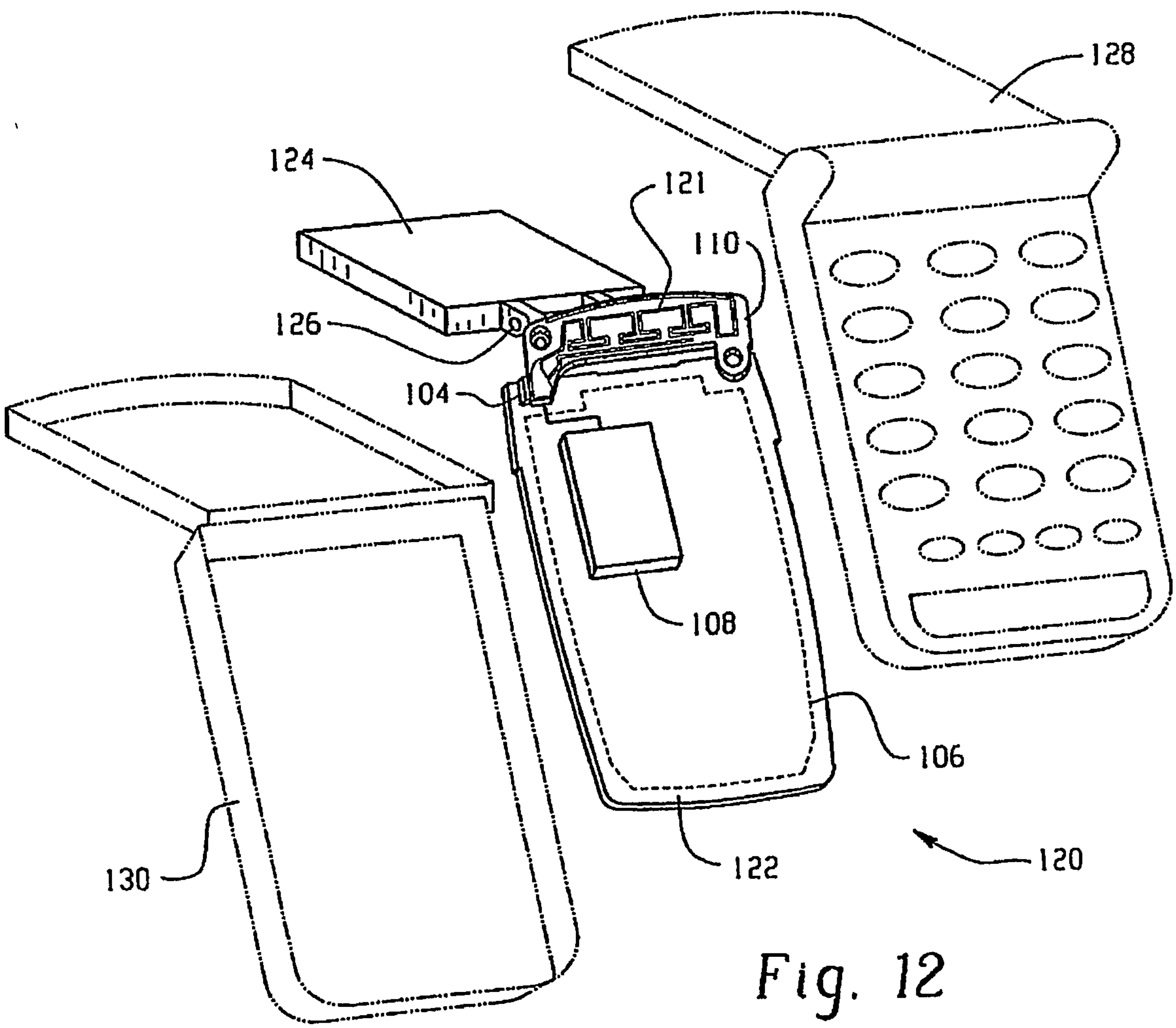
128
124
121
110
126
104
108
106
130
122
120

Fig. 12

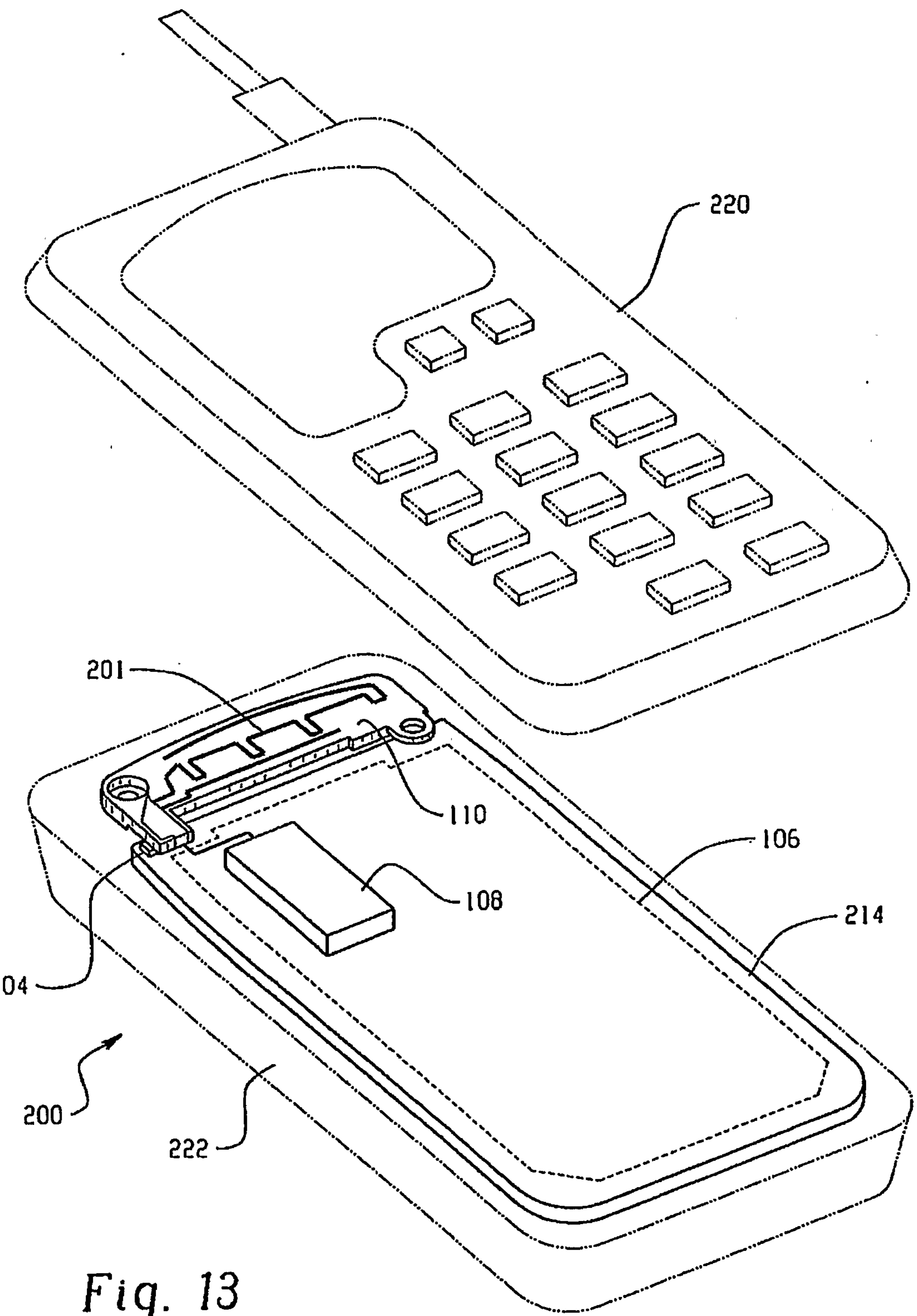

Fig. 13

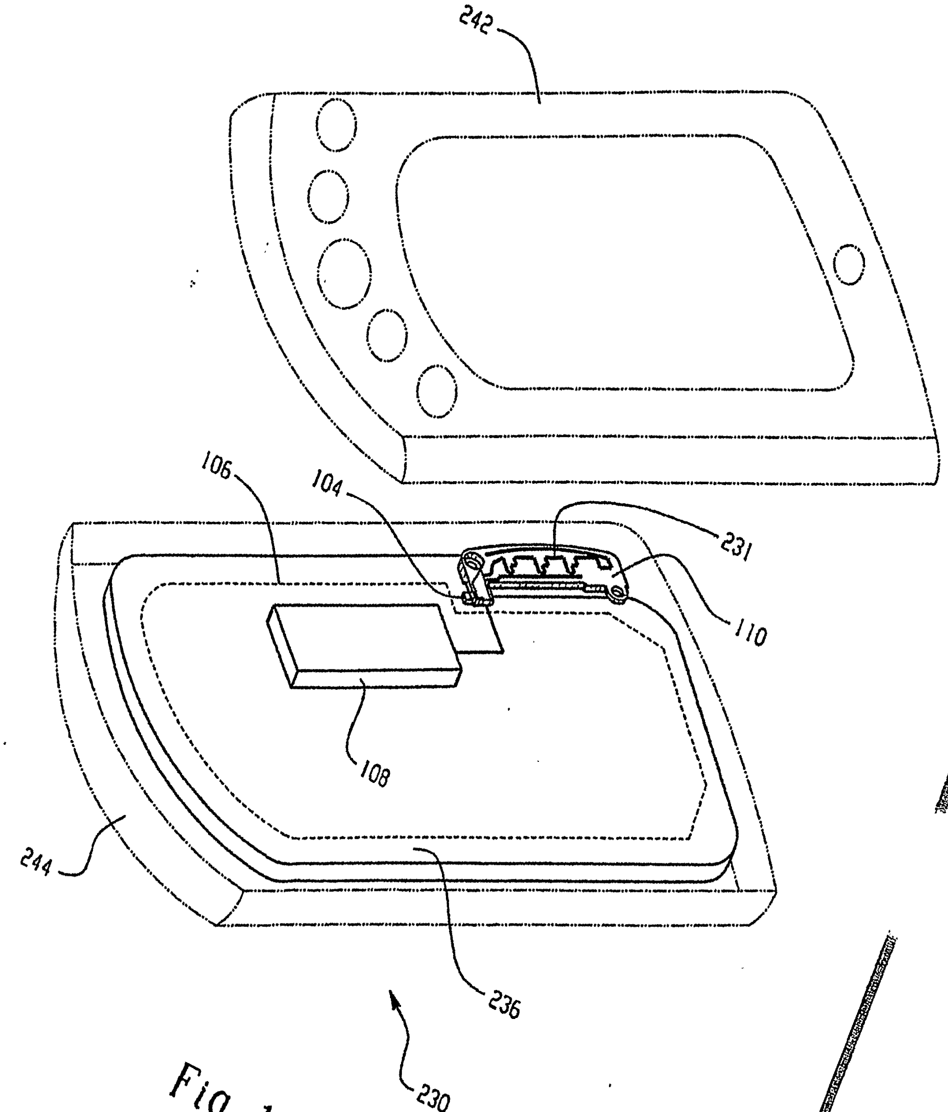

Fig. 14

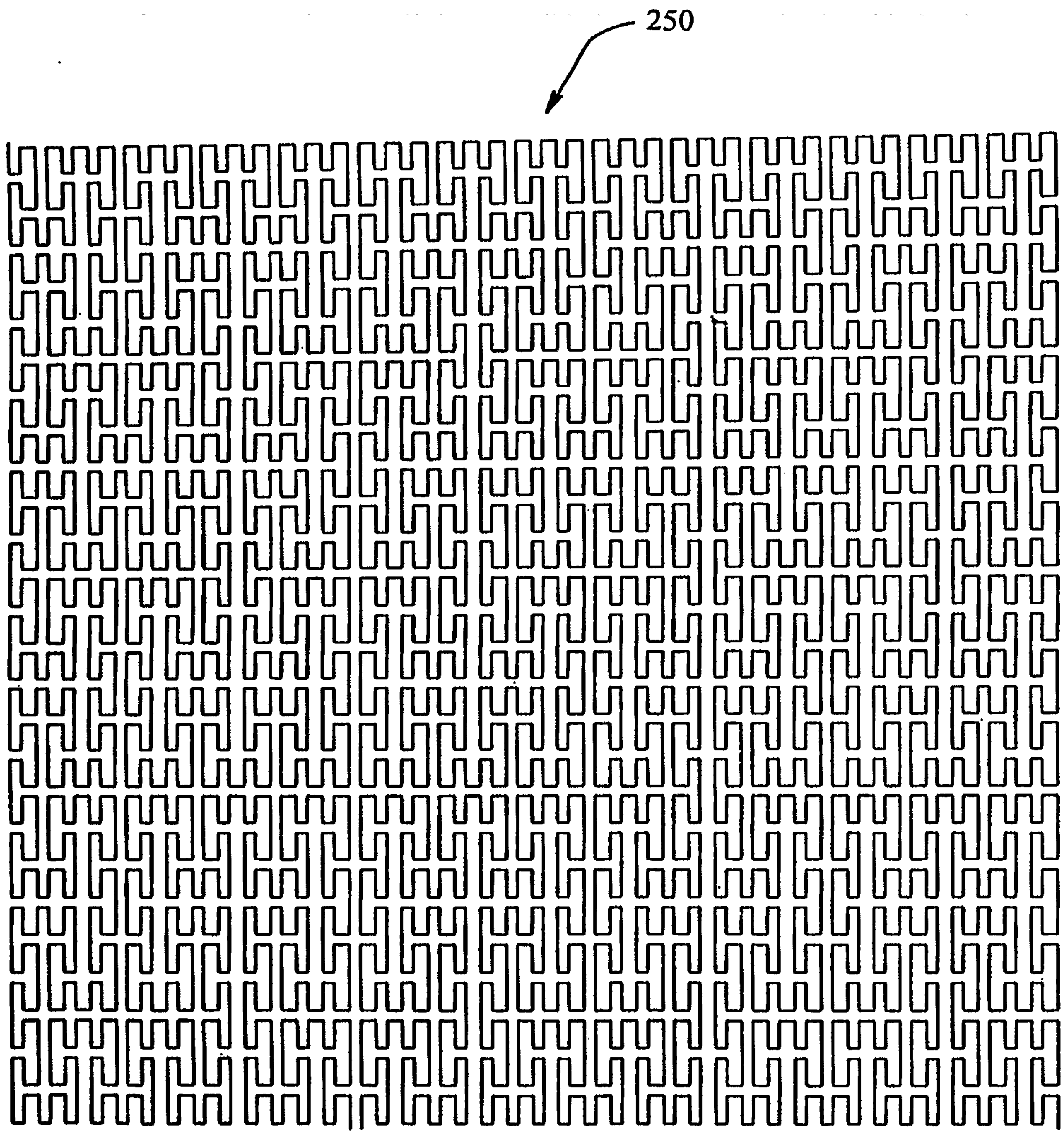

Fig. 15

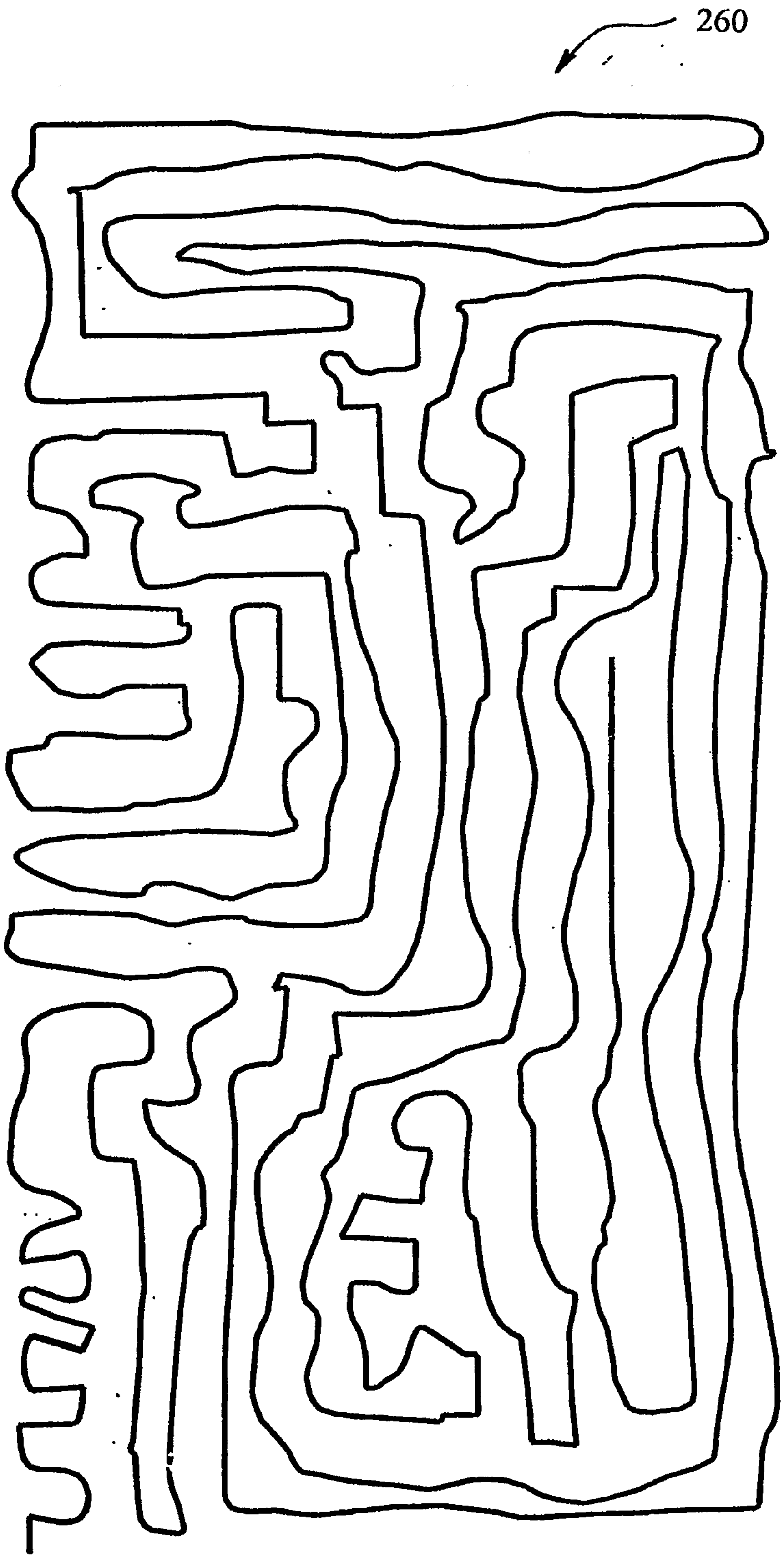

Fig. 16

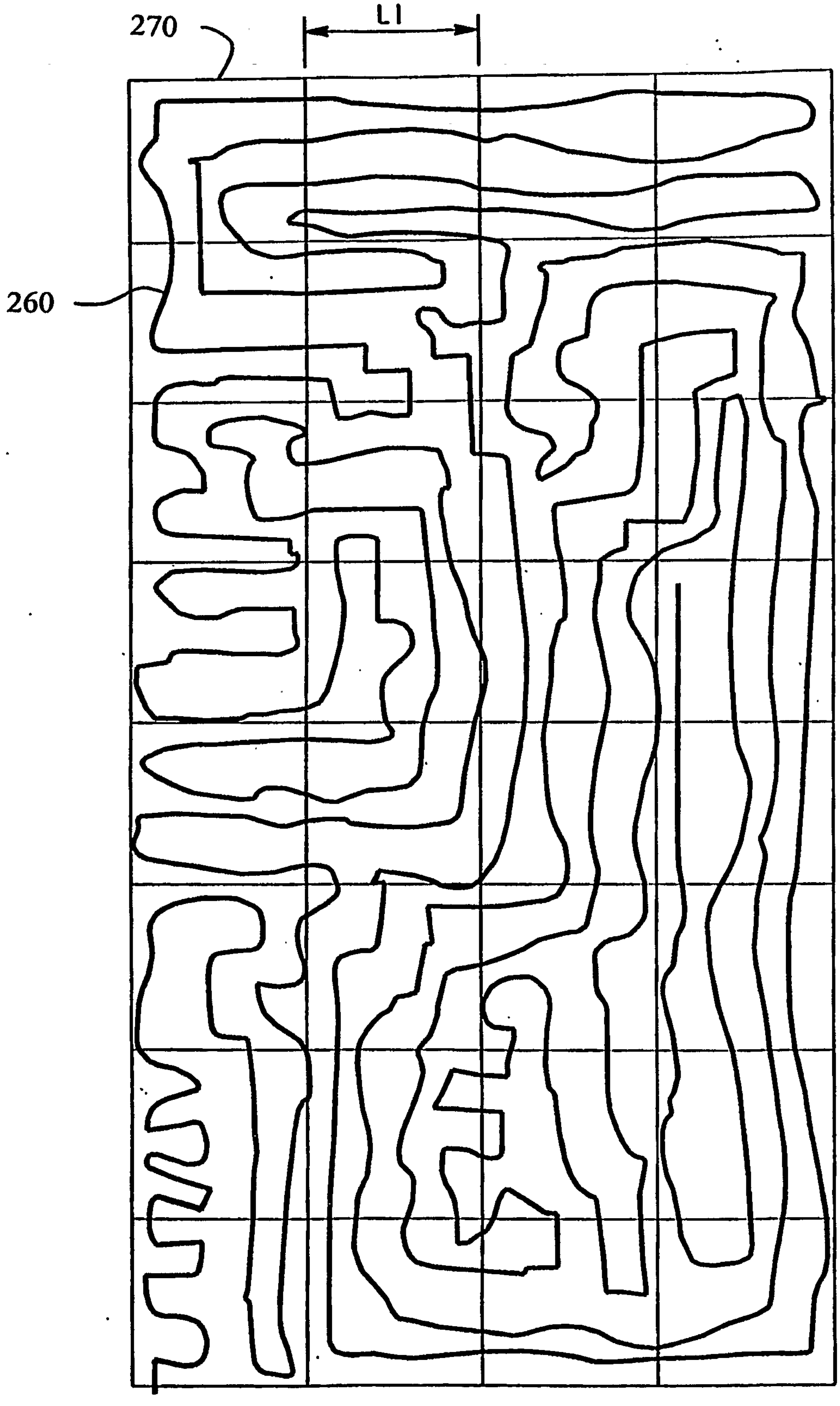

Fig. 17

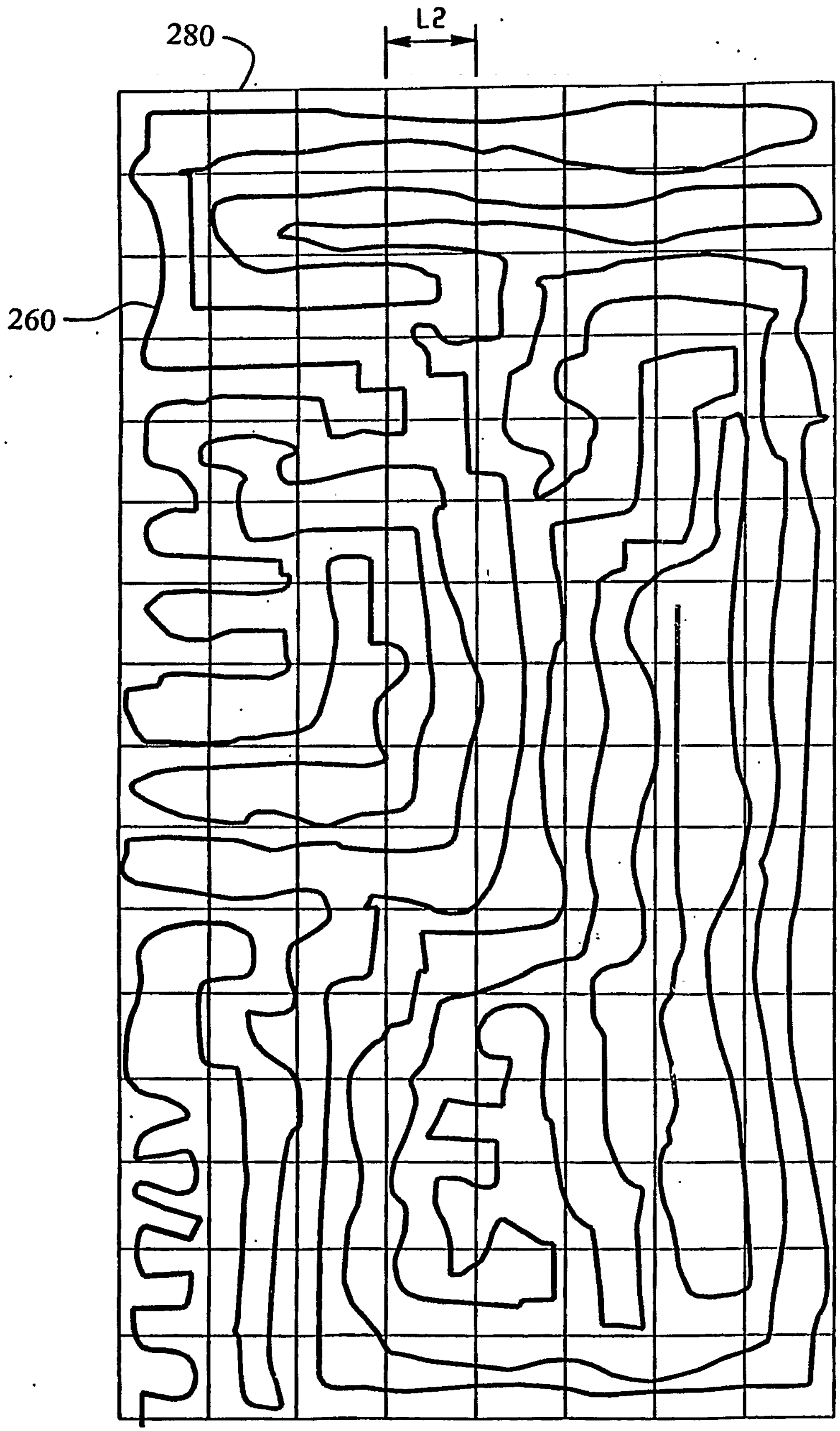

Fig. 18

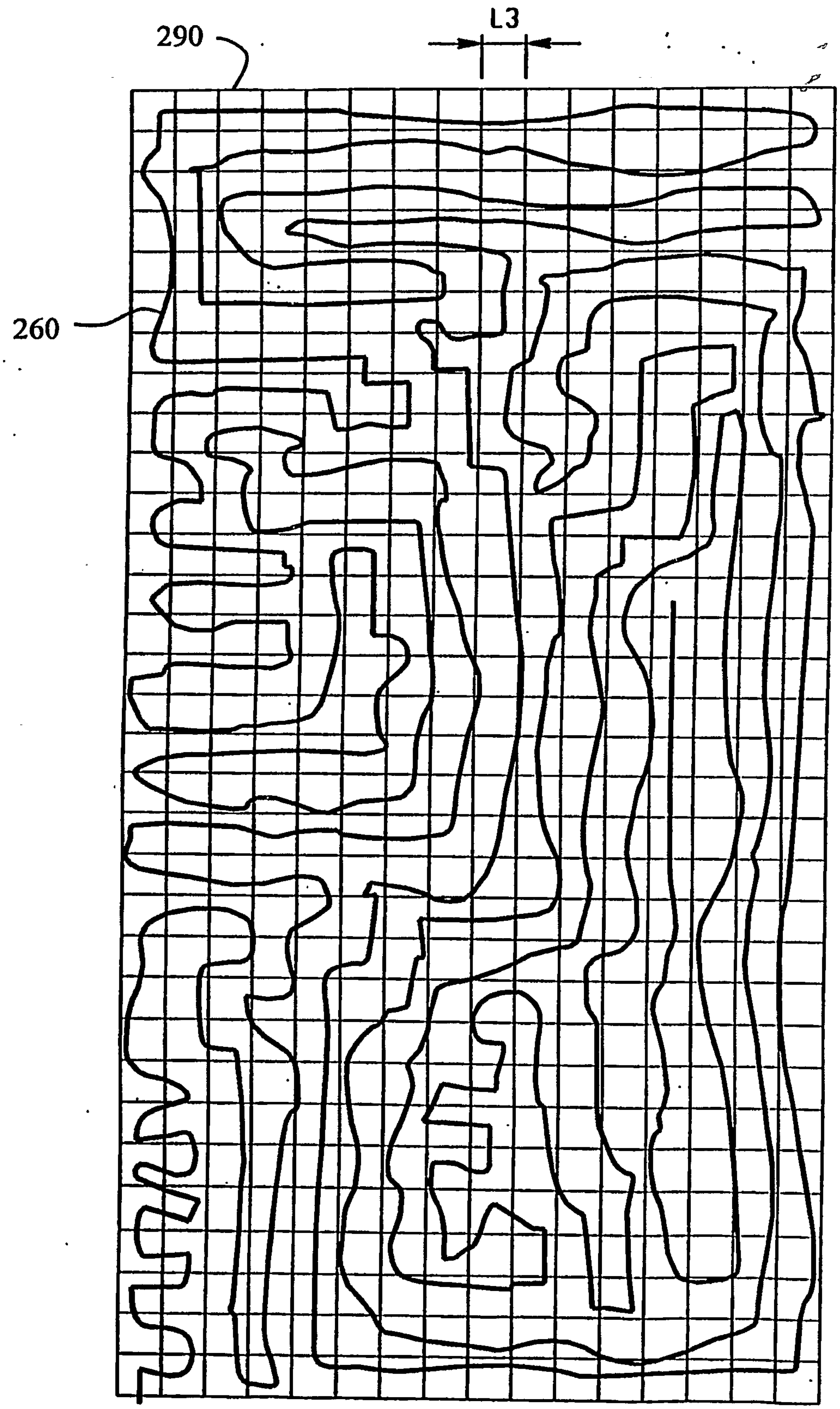

Fig. 19

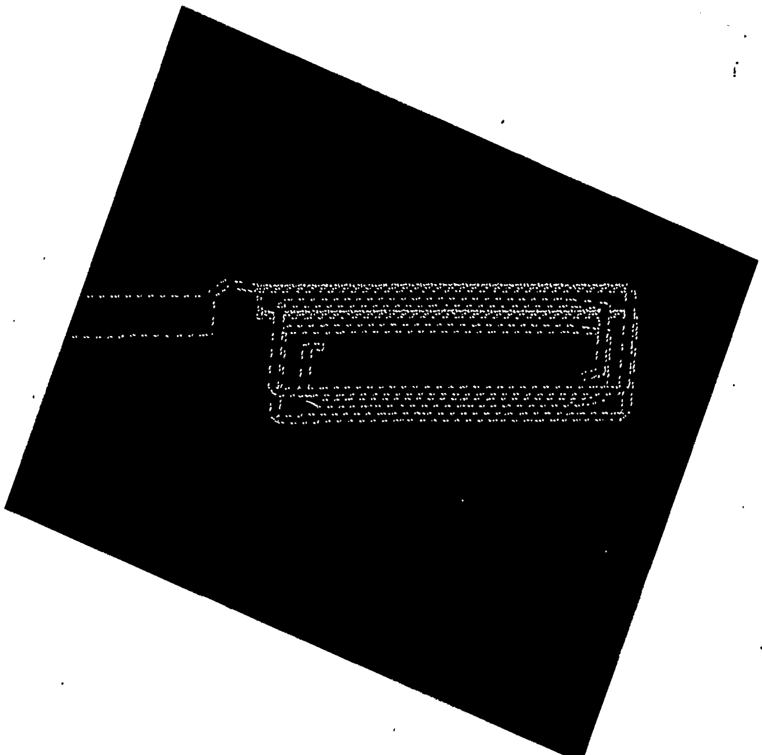

Fig. 20

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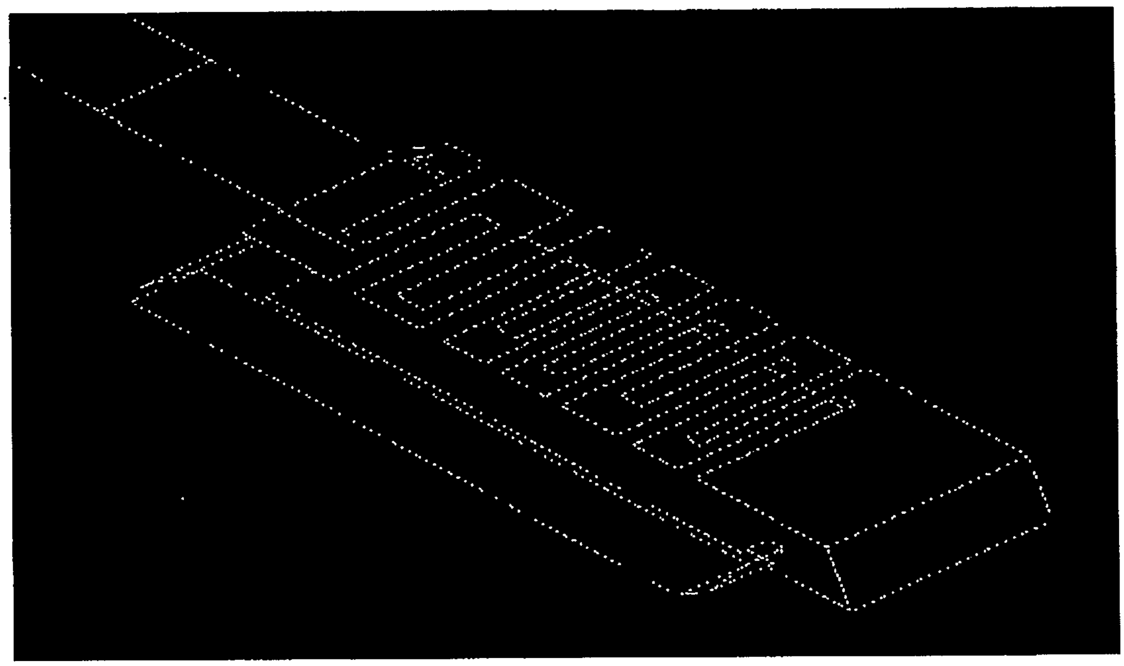

Fig. 21

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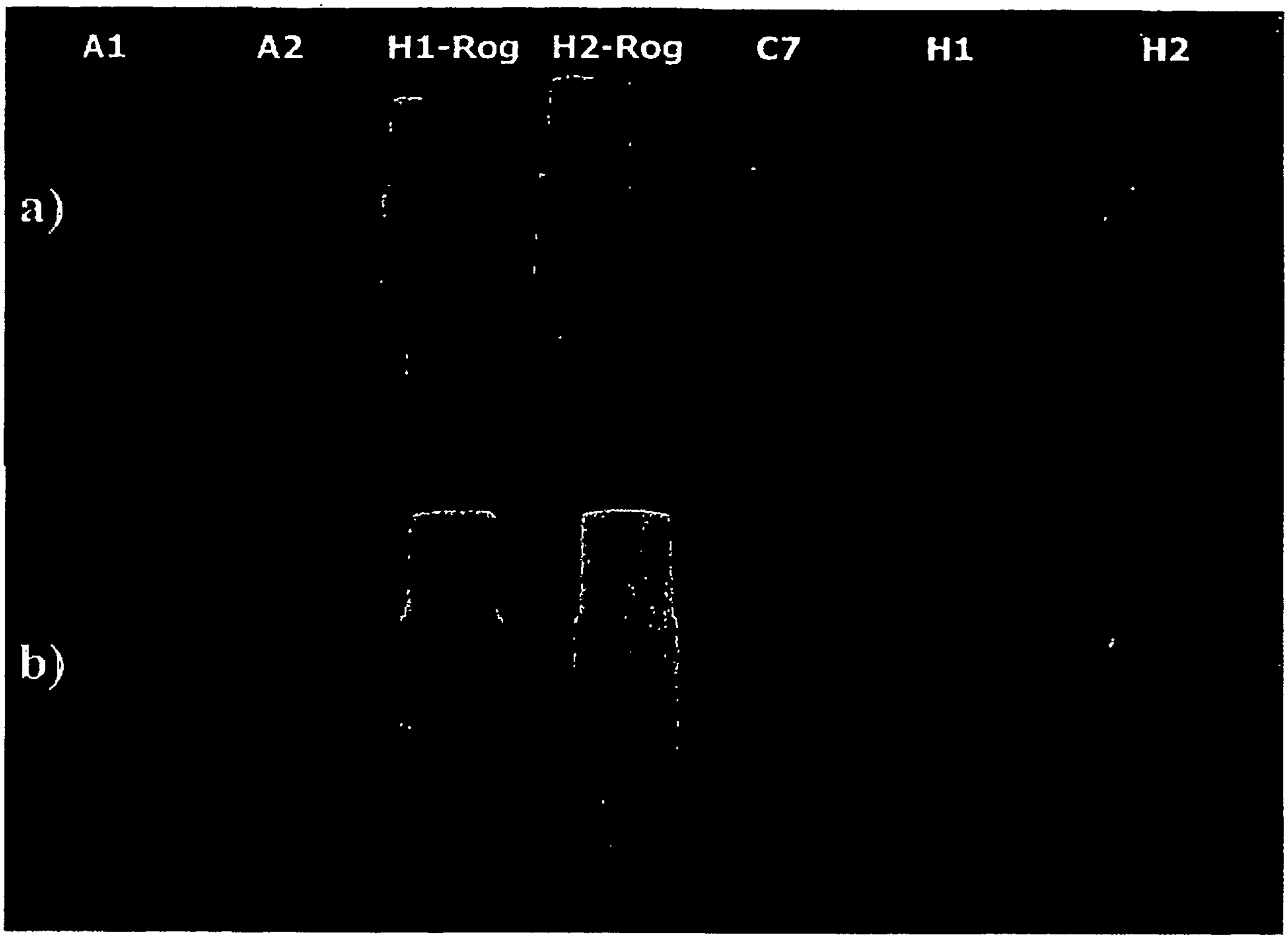

Fig. 22

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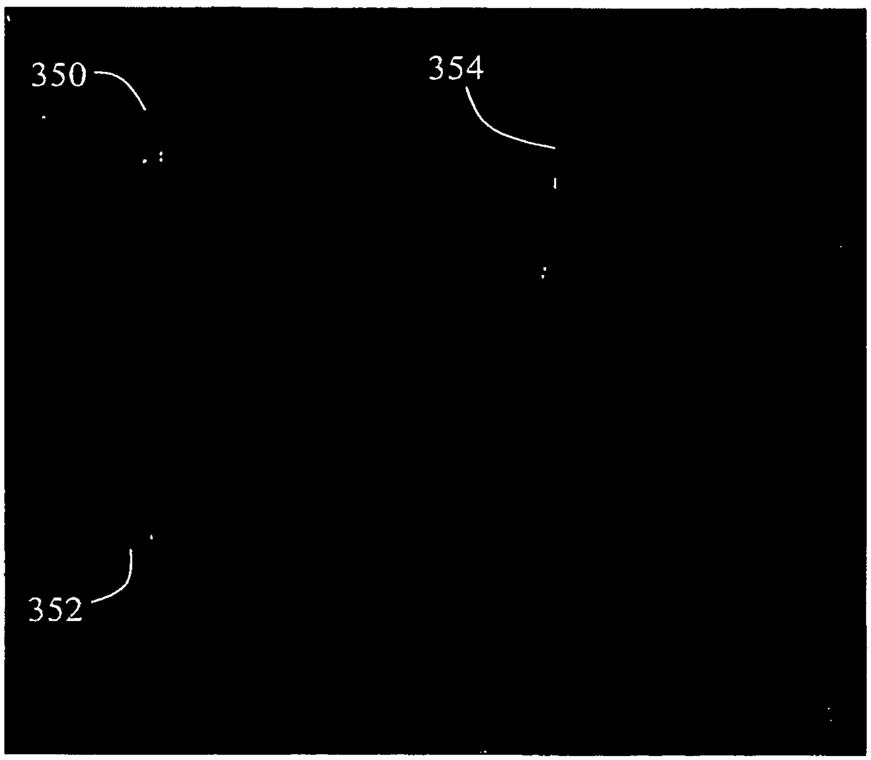

Fig. 23

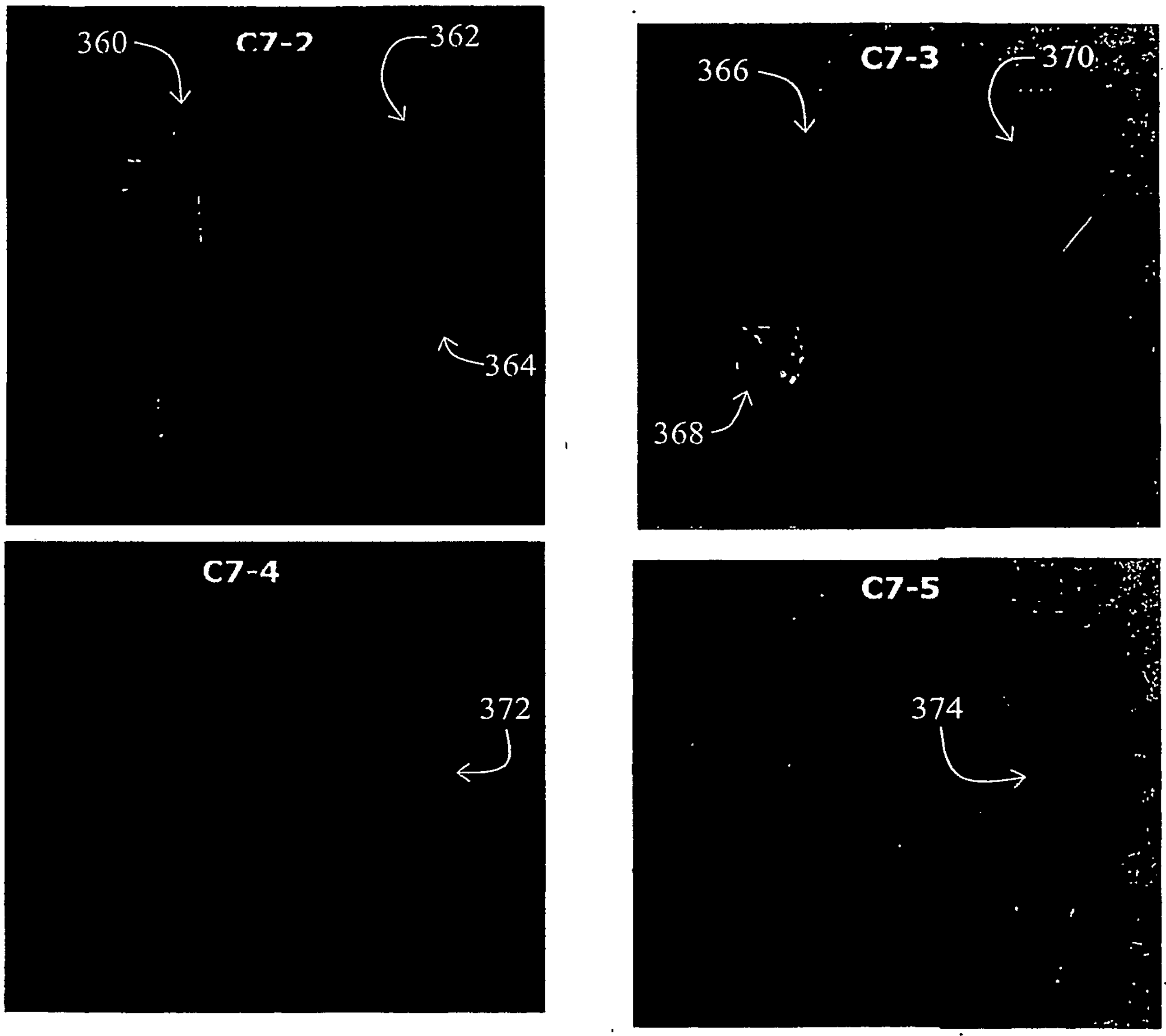

Fig. 24

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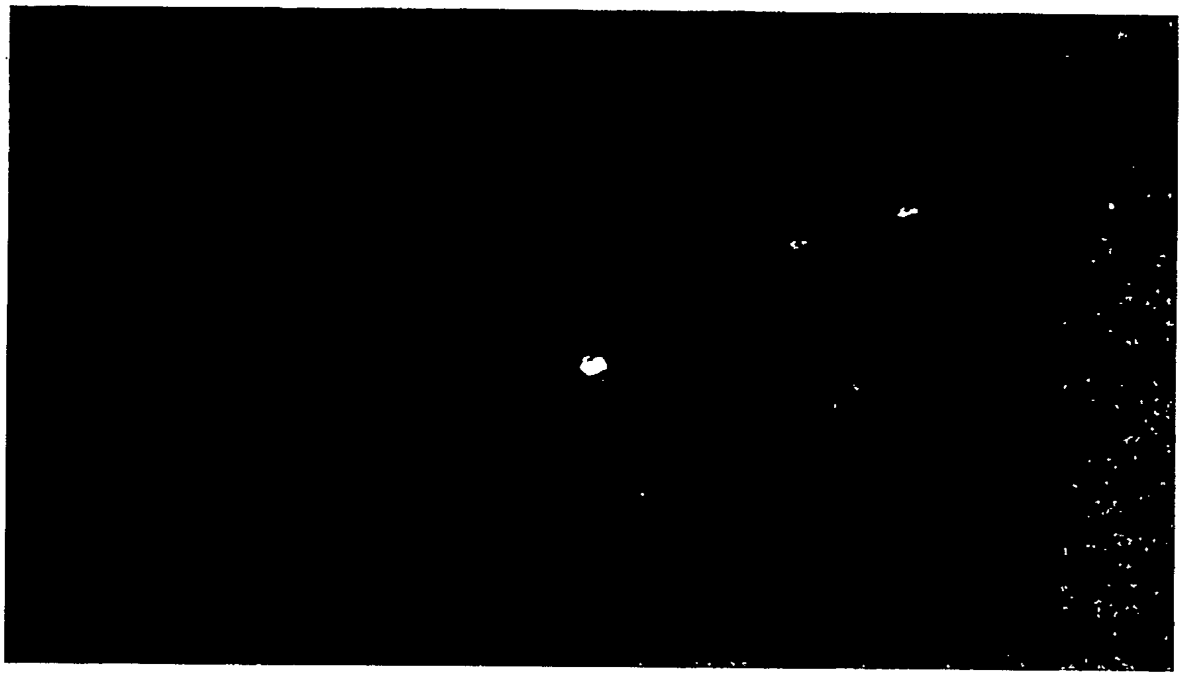

Fig. 25

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